B1 cont.

source coordinates to referenced geographic coordinates, which are typically in standard latitude/longitude. An image or a vector file is georeferenced to be used within a mapping/geographic environment. In a vector map, the data from which the map is drawn will typically already include a geographic coordinate set.

Please amend the paragraph extending from page 10, line 5 to line 16, of the specification to read as follows:

B2

When four or more georeferencing point-pairs are determined, the general linear georeferencing functions are over-determined. This means that more than the required amount of information to compute the general linear georeferencing functions is available, but that it is not, in general, completely consistent. The system uses the extra information contained in the additional georeferencing points to provide validation checks to protect against the possibility that some of the data points may be inaccurate **(step 430)**. Points that deviate excessively with respect to a calculated standard error are presumed to be inaccurate and are omitted from the calculation of the georeferencing functions. Note that as new points are added, the system also rechecks points previously marked as inconsistent, to determine if those points should now be considered when recomputing the georeferencing functions.

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Please amend the two paragraphs extending from page 10, line 22 to page 11, line 3, of the specification to read as follows:

The user may then proceed to enter the next point-pair **(step 440)**. When the user is finished, the system stores the active georeferencing functions with the raster-map **(step 445)**. At this time, the raster map is considered fully georeferenced. When accessed at any future time, the system may simply retrieve the georeferencing functions, and apply them to find the latitude and longitude of any point on the raster map.

B3

The process of determining the georeferencing function set from a set of point-pairs is believed to be within the ability of one of ordinary skill in the art. The specific approach used by the system and method of the preferred embodiment is discussed below.

Please amend the one line paragraph on page 11, line 15, of the specification to read as follows:

B4

$$\hat{f}(x_i, y_i) = (Lon_i, Lat_i) \quad for\ i \in A \tag{1}$$

Please amend the paragraph extending from page 11, line 16 to line 24, of the specification to read as follows:

Once determined, $\hat{f}$ will be the georeferencing function which is used to compute corresponding latitude and longitude values (Lon, Lat) for any point (x, y) on the bitmap. There are any number of possible ways to define the function that "comes closest" to making (1) true. We shall follow a "least squares" approach also known in mathematics as an L_2 approach. This approach seeks to find the function, $\hat{f}$, which minimizes

B5

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B5 cont.

the sum of the squared differences between the actual and the predicted values of latitude and longitude. In other words, from among all the functions $f \in F$, $\hat{f}$ is the one which minimizes:

Please amend the paragraph extending from page 12, line 1 to line 3, of the specification to read as follows:

B6

Among various alternative methods for choosing the function $\hat{f}$ are choosing it so that it minimizes the sum of absolute errors (rather than squared errors), or so that it minimizes the largest error. Other criteria are also possible.

Please amend the paragraph extending from page 12, line 11 to line 22, of the specification to read as follows:

B7

The General Linear Case: In the general linear case, we let F be the set of all possible linear transformations which map from (x, y) to (Lon, Lat). Thus,

$$\hat{f}(x,y)=\begin{bmatrix}\hat{a}_{11} & \hat{a}_{12}\\ \hat{a}_{21} & \hat{a}_{22}\end{bmatrix}\begin{bmatrix}x\\ y\end{bmatrix}+\begin{bmatrix}\hat{b}_1\\ \hat{b}_2\end{bmatrix} \qquad (3)$$

for some choice of parameters $\hat{a}_{11}$, $\hat{a}_{12}$, $\hat{a}_{21}$, $\hat{a}_{22}$, $\hat{b}_1$, and $\hat{b}_2$. If the region covered by the map to be georeferenced is not too large, then this family of functions will contain a suitable function $\hat{f}$ whose total error is quite small. In the case where the map to be georeferenced covers a larger area than this, then the curvature of the earth must be taken into

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b7 cont.

account and F is not a suitable family of functions. In such a case, nonlinear functions must be used as mentioned above. We shall not pursue that case further, since it is a straightforward extension of the procedures used in the linear case.

Please amend the paragraph extending from page 12, line 23 to page 13, line 2, of the specification to read as follows:

b8

To find $\hat{f}$ we seek the parameters which minimize

$$SSE = \sum_{i \in A} (a_{11}x_i + a_{12}y_i + b_i - Lon_i)^2 + (a_{21}x_i + a_{22}y_i + b_2 - Lat_i)^2 . \qquad (4)$$

The parameter values which minimize this expression are found by solving the following two independent systems of linear equations:

Please amend the paragraph extending from page 13, line 8 to page 14, line 2, of the specification to read as follows:

b9

These systems can be easily solved by well-known methods, such as Gaussian Elimination or LU factorization. The solutions yield the desired values of $\hat{a}_{11}$, $\hat{a}_{12}$, $\hat{a}_{21}$, $\hat{a}_{22}$, $\hat{b}_1$, and $\hat{b}_2$. It should be noted that equations (5a) and (5b) do not have a unique solution unless three or more non-colinear points are contained in A. Generally speaking, then, it requires 3 points to choose a georeferencing function from the family of general linear transformations. When there are four points or more, it is possible to compute a standard deviation of errors using the formula:

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$$s = \sqrt{\frac{\sum_{i \in A}\left[\left(\hat{a}_{11}x_i + \hat{a}_{12}y_i + \hat{b}_1 - Lon_i\right)^2 + \left(\hat{a}_{21}x_i + \underline{a_{22}y_i} + \hat{b}_2 - Lat_i\right)^2\right]}{n-3}} \quad (6)$$

b9 cont.

where s is an estimator for the amount of error to be expected between actual and predicted latitude and longitude values.

Please amend the two paragraphs extending from page 15, line 15 to page 16, line 10, of the specification to read as follows:

The parameter values which minimize this expression are found by solving the following system of linear equations:

B10

$$\begin{bmatrix} n & 0 & \sum x_i & -\sum y_i \\ 0 & n & -\sum y_i & -\sum x_i \\ \sum_{i \in A} x_i & -\sum_{i \in A} y_i & \sum_{i \in A}\left(x_i^2 + y_i^2\right) & 0 \\ -\sum_{i \in A} y_i & -\sum_{i \in A} x_i & 0 & \sum_{i \in A}\left(x_i^2 + y_i^2\right) \end{bmatrix} \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \end{bmatrix} = \begin{bmatrix} \gamma \sum_{i \in A} Lon_i \\ \sum_{i \in A} Lat_i \\ \gamma \sum_{i \in A} x_i Lon_i - \sum_{i \in A} y_i Lat_i \\ -\gamma \sum_{i \in A} y_i Lon_i - \sum_{i \in A} x_i Lat_i \end{bmatrix} \quad (8)$$

These systems can be easily solved by well-known methods, such as Gaussian Elimination or LU factorization. The solutions yield the desired values of $\hat{\beta}_1$, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$ which in turn yield the desired values for $\hat{a}_{11}$, $\hat{a}_{12}$, $\hat{a}_{21}$, $\hat{a}_{22}$, $\hat{b}_1$, and $\hat{b}_2$.

It should be noted that equation (8) does not have a unique solution unless two or more points are contained in A. Generally speaking, then it

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requires two points to determine a georeferencing function from the family of rotational linear transformations. When there are three points or more, it is possible to compute a standard deviation of error, s using the formula:

Please amend the paragraph extending from page 16, line 18 to page 17, line 4, of the specification to read as follows:

Automatic Error Detection and Handling

When individual points are being assigned x, y, Lon, and Lat values, there is always a potential for error. To reduce the risk of incorrect georeferencing resulting from such errors, certain error handling procedures are built into the georeferencing process. The fundamental concept is that of detecting a "bad" point and then removing it from the set of active points, A. Note that removing a bad point from A will not delete the information associated with that point, but it will cause the georeferencing parameters to be completely uninfluenced by that point. We do not wish to remove the point entirely, since it may be determined at a later stage of the georeferencing, that the point was not really bad at all, and should be used in the georeferencing calculation. This will be clarified shortly.

Please amend the paragraph extending from page 17, line 6 to line 17, of the specification to read as follows:

Detecting Bad Points The following steps outline the bad point detection process using the general linear transform approach to georeferencing.

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B12

1. Begin by placing all existing points into the active set, A.

2. If there are fewer than five active points then you are done. Otherwise, for each of the currently active points in turn, move it (call it point k for the sake of convenience) temporarily out of the active set, and then calculate the resulting inverse georeferencing function (call it $\hat{g}^{(k)}$) and its corresponding SSE_k. Also, calculate the difference between the predicted value and the actual value $\delta_k = \left\| \left[\hat{g}^{(k)}\right] \underline{\hat{g}^{(k)}}(Lon_k, Lat_k) - (x_k, y_k) \right\|$. Make a note of the values, $\delta_k and \delta_k / SSE_k$. Return point k to the active set and move on to the next value of k.

Please amend the paragraph extending from page 18, line 2 to line 13, of the specification to read as follows:

B13

There are several things to note about this procedure. One is that it allows the value of c_1 and c_2 to change with the number of active points, making it possible for the georeferencing system and method to utilize points which it might originally determine bad or inconsistent after a large enough sample of points has been gathered to make it clear that a lesser level of accuracy is all that can be achieved on this map. Another observation is that by using this procedure it is impossible to reduce the number of active points to less than four (unless you started with less than 4 in which case this procedure does not apply at all). This scheme means that as each new point is added, all points determined so far are

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considered, even those that had previously been marked bad. Thus early "misjudgments" on the part of the system can be corrected later, in light of new point information.

B13 cont.

Please amend the paragraph extending from page 18, line 23 to page 19, line 16, of the specification to read as follows:

B14

A specific example of the operation and application of the preferred georeferencing method may be shown with reference to the "Flood Zone Determination" business. The Federal Emergency Management Agency (FEMA) publishes a library of tens of thousands of paper maps showing various types of flood zones and their locations in the United States. A flood zone determination on a property is frequently done in the following way:

1. The address of the property is examined, and the location of the property is determined (perhaps through the use of a geocoding system, or by examining an available street map).

2. A map analyst attempts to determine which of the many thousands of FEMA flood maps will contain this property.

3. The map analyst goes to a map storage area and retrieves the desired map, often examining several maps before making a final selection.

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4. Having retrieved the paper map, the map analyst next determines where, precisely, the property is located on the map.

B14 cont.

5. Finally, the map analyst examines flood zone notations on the map at the property's location in order to determine its flood-zone status.

Please amend the paragraph extending from page 20, line 5 to line 19, of the specification to read as follows:

Using georeferenced flood map raster images, steps 2 and 4 above, are replaced by:

B15

2. A computer system combines the pre-designated outlines of the raster map and the georeferencing information to obtain a polygon expressed in terms of latitude and longitude that outlines the region included in each flood map. Then the system determines which of the polygons contain the address in question, which is done using a "point-in-polygon" algorithm. At the conclusion of this process, the computer system has identified a map panel (or perhaps a small number of map panels) that contains the address.

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4. Since the latitude and longitude of the property are known (by virtue of a geocoding phase), the computer system can use the georeferencing of the map panels to locate the property on